On the Importance of Spatial Perception for the Design of Adaptive User Interfaces

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Abstract—Automatically changing interfaces, such as Adaptive User Interfaces, are employed in state of the art software products, applications for mobile devices and web sites. While previous work has reported that some adaptive approaches to user interfaces achieve a low user satisfaction score, it has also been shown that they obtain a higher user performance score when compared with their static equivalent. This phenomenon has not been further investigated by previous research. The motivation of this paper is to further investigate this issue and consequently propose design principles for automatically changing interfaces. This is achieved by a fourfold contribution: a literature review of the current state of the art research of interface adaptation methods, the identification of the importance of spatial properties of interface elements (such as position, orientation and size) based on the review, a second literature review of human capabilities and limits that affect the perception and interpretation of spatial changes and lastly design principles for Adaptive User Interfaces are proposed that are derived based on the two literature reviews.

I. INTRODUCTION

Most Human-Computer-Interaction (HCI) users interact in their own way with a Graphical User Interface (GUI). Adaptive User Interfaces (AUI) are GUIs, that automatically change their appearance to address the individual needs of specific users. Research shows that AUIs can successfully solve common problems in HCI, such as solving conflicting needs between different user groups [1], focusing on the important and omitting what is unused and unwanted [2], enabling the user to find what they use frequently [3]–[5], or to find what they do not know so far [6], [7]. Figure 1 depicts a smartphone with an AUI, showing a list of the most recent calls in descending order and tiles of the most frequently called contacts, from left to right.

A. Problem Description, Motivation and Contribution

Although various adaptive designs have been created and evaluated, no dedicated design principles for AUIs have been proposed in the literature, which is problematic [8], [9]. Design guidance from the realms of static design can be partially applied considering rules for good design, usability and user experience [10]–[13], but these rules do not cover the characteristic of an AUI: it changes its appearance over time, often also during runtime.

AUIs are nowadays employed in commercial software, such as operating systems for desktop computer, mobile devices, ebook reader, etc. Also web-based platforms and mobile friendly websites employ adaptive means by responsive design [14], [15]. Major software companies claim to provide design principles to guide AUI design, but these principles do not address the nature of AUIs to change the interface during runtime. They address context related aspects like designing for different screen sizes, different device classes and adjusting the text size properly which does not change during runtime [16]–[18]. The example of the smart menus, employed in Windows XP and the Office 2000 Suite, illustrates the insufficiency of this approach: Unused elements are hidden within the smart menu and replaced by a small arrow indicating that a hidden item can be revealed again. Users dislike that behaviour [19]. As the elements have been omitted, users forget the origin position of these elements and can not find it anymore. Frustration arises and the utility of the system decreases.

The existing principles do not consider the capabilities and limitations of humans in how they perceive or deal with spatial properties such as position, orientation and size and are therefore insufficient when designing an interface that changes spatial properties, especially during runtime. Interfaces that do not change spatial properties are considered spatially stable.

This paper contributes to the AUI research domain by outlining the importance of spatial perception for AUI design.
The remainder of the paper presents an extensive literature review, consolidates AUI experiment findings and describes the impact of human capabilities and limits in relation to spatial perception and information processing on AUI design.

II. STATE OF THE ART ON ADAPTIVE USER INTERFACE RESEARCH

User performance (UP) and user satisfaction (US) are relevant measures to identify the success of adaptive techniques. The techniques are used to promote elements that are considered relevant for the user, most commonly frequently and recently used elements. There are also other possibilities to predict relevance based on stochastic models [7]. There are 15 distinct techniques which differ significantly in UP and US which are briefly introduced in the following subsection.

A. Visual Adaptation Techniques

Adaptive defaults pre-populates user input fields with content that has been learned in the past as being entered frequently in the corresponding fields [20]. This implies the need for a user data log, which is used as training data to increase the quality over time. Such a feature is employed by modern web-browsers where it is called autofill.

Colour Highlight highlights relevant items by applying a different colour to the items [3], [21]–[23]. Colour modification and resizing can be combined [21].

Customization supports the manual adaptation of the interface by letting the user customize functions, interaction possibilities and the visual layer [24]. Adaptable interfaces can be directly customized without a customization menu [25]–[27]. Mixed-initiative is a semi automatic customization technique that automatically identifies the "best" changes to the interface, allowing the user to accept or reject the new interface [28], [29].

Eliding is used to hide rarely used and thus less relevant items to provide a clean looking interface in order to promote the remaining items [2]. Usually an undo function is placed nearby to reveal the hidden items again.

Ephemeral Adaptation provides an animation to gradually fade-in less relevant items, thus highlighting the relevant items by instantly presenting them [22].

Font Highlight highlights relevant text labels by changing the font style. In most cases a bold style is employed for the highlight, whereas the regular style is employed for the remaining labels [26], [27].

Inserting is used to promote highly relevant content by generating a link to it and inserting the link on a visual prominent level [6], [30], [31]. The difference to moving or replicating is, that the item did not exist before, but has been generated to, e.g. access aggregated features by one short cut, like dynamic search facets.

Moving is used similarly to replicating, but instead of coping the items into the adaptive area, they are moved from their origin location [3], [25], [32]–[34].

Progressive Enhancement & Graceful Degradation employ sets of interaction widgets. Each set enables the user to perform the same operations in a different way, tailored to the interaction environment and user preference. Sophisticated systems automatically up- or down-scale each widget within each set according to the target device’s properties or user preferences by replacing [5], [35].

Removing works similar to eliding with the difference that no possibility is provided to display the hidden elements again [36].

Replicating is used to promote relevant items in a dedicated adaptive area [3], [4], [6], [37]. The items are copied into this area, not moved.

Resizing highlights relevant items by changing their size [21], [38], [39]. Fitts’s law is often employed to calculate the corresponding size [38].

Scrutability provides transparency for the user to reveal why a certain adaptation has been performed [40], [41]. It is not a visual adaptation technique on its own and can be combined with any other technique presented here. A scrutable system aims to improve trust and predictability.

Transition Screens are mostly used to serve the different needs of an expert and a novice user, allowing the novice user to become an expert by transitioning to the expert screens, once the system considers the user to be an expert [1].

Visual Indicators are any visual elements that are used to highlight relevant items, comparable to the colour modification. A visual indicator is a graphical element that is placed nearby the item to highlight. The appearance of the indicator does not change over time. It is switched on and off according to the adaptive algorithm.

B. Algorithm vs. Visual Adaptation Technique

Accuracy is a metric that describes the percentage of how often the AUI is able to offer the item that the user required [4], [21], [42]. E.g. when the user requires five specific functions and four of them are correctly predicted as relevant and thus presented within an adaptive list menu, this interface element has an accuracy level of 80%. If the level of accuracy decreases below 50% the subjects will start to feel frustrated and perceive that the suggestions are regularly incorrect [21]. Therefore, the level of accuracy affects how the whole AUI is perceived, although accuracy results from the quality of the adaptive algorithm and not from the quality of the visual adaptation technique.

Although the importance of the adaptive algorithm’s quality on the overall AUI quality has been researched in detail, the question still remains, why some adaptive designs with a high accuracy level score low in terms of US despite their high UP score. The answer can be provided by human factors. Human factors are the body of knowledge about human abilities, limitations and characteristics that are relevant to design, including the domains of psychology, social sciences, brain research, etc. This knowledge is incorporated to create more appealing and user friendly products.

III. ASSESSMENT AND IMPORTANCE OF HUMAN FACTORS

The human nature has a special relation to spatial related stimuli and effects. This is illustrated by Baddeley’s multi-component working memory model, describing the interplay...
of distinct components in the brain to process environmental stimuli [43]. Visual stimuli are always processed in a spatial relation, thus the component to process and alter visual stimuli has been named the viso-spatial sketchpad. E.g. when memorizing geometric shapes, also their relative position is memorized [44].

To assess which human factors are important in order to derive AUI design principles, the most relevant comparative research of AUI designs needs to be assessed with respect to effects related to the human nature. Table I on the next page provides an overview of this literature review. Each comparative study is enlisted with the number of subjects which participated in the test (N), if the evaluation metric of accuracy has been employed to ensure comparability of the different AUI designs within the test setting and if the adaptation technique causes changes to the space related attributes of the user interface. The main findings measure the UP and US of the different designs. If two techniques score similar, they are indicated by an equal sign (=), if a technique scores higher than another they are separated by a greater than symbol (>). The main findings of each study presented in the table are the basis to assess every adaptation technique, which is described in the following.

Adaptive defaults are well researched and established in web browsers. Their functionality increase UP and US. It would be worthwhile to consider integrating this functionality in operating systems to increase the range of helpful support.

Colour Highlight should be perform very well, as colour is the best single coding dimension and suited to communicate qualitative changes [47, p. 100], but achieves contradicting results: in the same study UP is low but US is high [23] whereas in another study UP is low and US is high [22], [3] measured only a low US but did not measure UP, [21] measured only a low UP but did not measure US. Users state that the technique causes distraction effects. This might be caused by the fact that colour is not only a coding dimension but also an element that contributes towards the hierarchical structure of information, the visual hierarchy [48]. The human factor of visual dissonance states that differently coloured elements catch attention exogenously, which is a too strong effect when the use case requires only a subtle hint and thus this technique is considered distracting.

Customization increases awareness of changes to the system. The user is able to understand the benefits provided by semi-automatic or manual improvements and thus knows where to find the changed feature [25]–[29]. This is a problem in AUIs, as the majority of users do not recognize the change, if it is not highlighted, e.g. by animations. In terms of establishing a mental representation of the function’s location, this approach is effective as it supports the human factor of the motor memory. But since employing customization is a very difficult task and users rarely customize [49], the approach will only be helpful in situations where conventional customization is expected.

Eliding and Removing seem to perform well when directly compared to a static baseline with regard to US and UP. However, both decrease the awareness of available functionality and can cause frustration [36], [45], because it is easier to identify a new item than to identify the lack of an item. The frustration might be caused by a human factor effect of the increasing discrepancy between the user’s mental model and the user’s conceptual model. The conceptual model is build based on the information which is communicated through the interface, the mental model is a belief pattern based on experiences that help the user to combine single pieces of information with existing knowledge and beliefs and react accordingly. Mental models let users predict and explain relations and unknown functions in the real world and also how an unknown system most likely works [50].

Ephemeral adaptation works well in the laboratory [22], but has a major practical disadvantage: the highlight of relevant items is not persistent. Maintain this indication by lowering the maximum transparency of the gradually faded-in elements would create a conflict with the design convention that items with reduced contrast are considered inactive, causing confusion by accidentally employing a wrong mental model. A reduction of contrast is automatically created by the reduced transparency.

Font Highlight compared to a baseline works better than colour highlight compared to a baseline, although it also performs not efficiently [26], [27]. However, considering the importance of maintaining the visual hierarchy due to the human factor of attention flow, it is to assume that changing the font style is less distracting than colour highlight.

Inserting is often employed for beneficial short cuts, thus providing an optional support. If the user does not recognize the inserted option she can continue to use the interface as she is used to, without failing to achieve her goal. Interestingly, this can decrease control, but at the same time increase US [31]. Furthermore, this technique is suited to encourage the user to explore the application.

Moving is rated rather high in either UP or US or both [25], [26], [32], [35] and low in [3], [27], [33]. However, this technique does not provide the fail-safe that replicating offers, therefore it is error prone for low levels of accuracy. Further, if the algorithm fails, it prevents the user from applying spatial knowledge about the whereabouts of the relevant function, forcing him to increase the mental effort to solve the problem. This can lead to frustration [25]. Moving should be applied carefully and only if the technique could provide a benefit for the use case when other adaptive techniques would not.

Progressive Enhancement and Graceful Degradation is often used in an unobtrusive way only, e.g. to adapt an interaction element, such as a drop-down menu, to environmental factors, like input modalities of the target device. This adaptation will not be perceived by the user as such, since it does not take place during the usage, thus maintaining spatial stability. Whereas, when applying these means during usage by generating an interface automatically [5] user reactions are quite unexpected: able bodied users perform faster with the dynamically generated interface, but dislike the approach in favour of the less performant but static equivalent, likely
because of the spatial stability caused by moving [3, p. 207]. Interestingly, motor impaired users favour the adaptive approach over the static version. The reason may be based on the human factor of psychological needs, that affect the interaction flow, even if the adaptive algorithm fails, because the user can still access the functions from where one [46]. The main problem of resizing interface elements according to their relevance is the potential to accidentally highlight the less relevant item due to the effect of the human factor of visual dissonance [52] or by the gestalt law of proximity and similarity [53], break the layout when minimum and maximum size limits are exceeded [46], or decrease the usability by increasing the effort required to navigate through the larger items [39].

**Scrubability** aims to provide self-managed freedom of a transparent system. Research shows that users favour usability and user experience over transparency, this applies even for scholars [54]. Therefore, the effort to make a system scrubable appears only appropriate in scenarios where creating trust is a mayor issue. Recommendation systems have to provide a certain level of scrubability in order to explain the different recommendation categories.

**Transition screens** support the expertise specific user requirements which change over time. But they cause confusion when transitioning from one screen to another [1], because the new conceptual model needs to be learned again and if poorly designed, relevant functions have been relocated and require a different interaction. The user is required to relearn the position and interaction, thus he is forced to reconfigure his mental model. It has been shown, that incremental changes are better accepted, than wholesale changes [55]. We can also assume that incremental changes slightly modify the mental model that has been shaped during the interaction and a wholesale change questions if the model is still applicable, forcing the user to relearn.

**Visual indicators** also insert elements and is therefore technically similar to inserting. The nature of visual indicators is to stick out and create a visual dissonance, e.g. red circular badges with a counter notify about the number of messages. Shape and colour harm the visual consistency of the other interface elements. Of course the strength of this effect depends on the visual design, but based on the human factor knowledge outlined in this publication, it is likely

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Accuracy</th>
<th>Spatial</th>
<th>Main Findings</th>
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<tbody>
<tr>
<td>[27]</td>
<td>30</td>
<td>x</td>
<td>✓</td>
<td>UP: adaptable &gt; font highlight &gt; eliding &gt; mixed-initiative &gt; moving. US has not been assessed.</td>
</tr>
<tr>
<td>[29]</td>
<td>12</td>
<td>x</td>
<td></td>
<td>UP: adaptable &gt; mixed-initiative due to more time required. US: anecdotal positive evidence for both.</td>
</tr>
<tr>
<td>[33]</td>
<td>63</td>
<td>x</td>
<td>✓</td>
<td>UP and US: static &gt; moving.</td>
</tr>
<tr>
<td>[38]</td>
<td>8</td>
<td>x</td>
<td>✓</td>
<td>UP: replicating (frequency) &gt; resizing = static &gt; replicating (recency). US not assessed.</td>
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<tr>
<td>[21]</td>
<td>12</td>
<td>✓</td>
<td>✓</td>
<td>UP: shrinking (resizing) and colour highlight &gt; static and colour highlight. US not assessed.</td>
</tr>
<tr>
<td>[23]</td>
<td>16</td>
<td>x</td>
<td>✓</td>
<td>UP: replicating &gt; static a) (strong hierarchy); colour &gt; static b) (flat). US: replicating &gt; static a); static b) &gt; colour.</td>
</tr>
<tr>
<td>[22]</td>
<td>12</td>
<td>✓</td>
<td>x</td>
<td>UP: ephemeral (slow) &gt; ephemeral (fast) &gt; static. US: ephemeral (slow) &gt; static &gt; ephemeral (fast).</td>
</tr>
<tr>
<td>[22]</td>
<td>24</td>
<td>✓</td>
<td>x</td>
<td>UP: ephemeral (slow) &gt; static = colour. US: colour &gt; ephemeral (slow) &gt; static.</td>
</tr>
<tr>
<td>[40]</td>
<td>17</td>
<td>x</td>
<td></td>
<td>UP and Trust: scrubutable &gt; non-scrutable approach. US not assessed.</td>
</tr>
</tbody>
</table>
that visual indicators are more likely to be recognized as inserted elements, as the indicators do not blend in with the interface environment [36]. Visual indicators have been rated as low as their static equivalent within a design that made strong usage of that technique [36]. However, the worlds most visited web sites like google.com, Youtube, Facebook, etc. employ this technique successfully by using it only for presenting notifications for features that users expect to change frequently.

IV. PROPERTIES OF PERCEPTION RELATED TO SPACE

Previously, adaptation techniques to visually change elements within the graphical user interface have been presented and assessed regarding their evaluation results. It has been pointed out which technique achieves a higher UP and US than others, but the reasons remained unclear as the occurrences in the previous section have not been further researched in the AUI context. It has been speculated, that the human nature to perceive visual elements is closely related to the perception of space and causes the different evaluation results. In order to find an answer, which would allow deriving design principles for AUIs, human factors that describe the capability and limits of human perception and information processing related to AUIs are described.

A. Attention Flow

Attention is part of the relevance interpretation process of the information that has been perceived. Attention channels mental resources to process perceived stimuli. It can be selective, focused and divided.

Attention is selective, because the memory capacity is limited and the brain has to filter apparently irrelevant information to focus on the most relevant. Therefore, humans forget to sample stimuli from a source the more stimuli sources are present. Humans tend to sample information from channels with frequent stimuli more often than information from channels with infrequent stimuli. E.g. a mail inbox for an account that receives usually a lot of emails will be checked for new mails more often than an inbox for an account that receives usually only a few mails. Further, humans sample more often than necessary, because they forget the last status, e.g. the user forgot if the mail inbox contained a mail that required action the last time she/he checked, therefore she/he checks the status again [47, p. 65]. In addition, information in areas that are considered important will be perceived more likely than information in areas that are considered less relevant [52, p.124].

Attention is focused, to focus on the most relevant information that is passed through the processing neurons. What enters the spot of attention is a question of spatial proximity, because information close to the focused information will be perceived as well [47, p. 66]. Therefore less information can be processed and less distraction occurs, e.g. when searching for an explicit keyword, other information is ignored directly after the relevance assessment. Focused attention is controlled consciously, linear and text-oriented. This pattern is activated when searching for explicit information [52].

Attention is divided, to enable multi-tasking, also known as timesharing, thus introducing performance drops on at least one of the tasks at hand [47, p. 66]. In this state the attention floats and can perceive peripheral information, by enabling one to shift the attention outside of the eye’s fixation point, see Figure 2. Therefore, more information is perceived as when searching for an explicit information and distraction can occur more likely. However, the strength of floating attention is its capability to pre-process peripheral information and subconsciously judge if the information is of interest or not [52, p.67]. This pattern is activated when browsing and not searching for explicit information.

Furthermore, the nature of the task affects the direction of attention flow [12, p. 23]. Everything that seems a priori not related to the task is filtered.

The properties of attention flow is also influenced by the physiological capacity of the short term memory. The capacity is limited to the maximum storage of 7 +/−2 items [56], thus what is not steadily visible is easily forgotten. It is recommended not to hide complexity in order to create simplicity, especially not with navigation elements, as users will not create a mental map tailored to the interactive system [13]. Steady visibility of the key functionality increases utilization of the features.

This is illustrated by the example of Redbooth, which changed from a hamburger menu to a tab bar and thus increased user sessions and overall session durations [57]. Zeebox, e.g., did it the other way around and exchanged a tab bar by a hamburger menu resulting in half the engagement than before [58]. A similar effect could be observed in the Polar App redesign [59]. A persistent segmented control has been replaced by a toggle menu that hid the control elements and would reveal them on tap. The user’s engagement immediately broke down, because they did not toggle the menu thus losing the ability to navigate thus losing interest in the application.

Furthermore, attention is controlled consciously (endogenously) or unconsciously (exogenously) [60]. Endogenous attention control is performed, e.g., when a user takes a look at the upper right corner of a web site, because she/he expects to be able to log in there. Exogenous attention control is performed, e.g., when an animated banner advertisement catches the user’s attention and without consciously deciding to do it,
she/he looks at the advertisement. Endogenous attention has a latency of around 200ms but can last for a longer period (>500ms) whereas exogenous attention responds very fast to a stimulus (around 50ms) [60]. A stimulation is able to trigger an exogenous attention shift automatically during an endogenous attention control, thus overriding the conscious choice [61]. The experience of where to find which type of interaction element or information is mentally modelled to cope with the visual complexity focus the attention to the location where the specific interaction element is expected [52]. Visual hierarchy has a strong impact on the attention flow. The viewing behaviour in text based web sites, which occurs for browsing as well as for direct search, can be disturbed by the use of images, i.e. the eye will focus the images directly, skipping textual information [48]. Without images the user reads the first line of text, skips a few lines and continues to read half a line of text. Independent if a line is read completely, the eye fixates the beginning of the line. This viewing behaviour is also called F-shape, because a heat map interpretation of eye-tracking data looks similar to the letter F.

Harming visual conformity can disturb exogenous attention shift [62]. Figure 3 depicts a comparison of a) a linear with b) a primary and c) an arbitrary television screen layout. When evaluating which layout receives the most attention the linear layout receives the most attention for the second and last screen from left to right, whereas the second is slightly more focused than the last. Within the primary layout the largest screen gets always the most attention. Surprisingly within the arbitrary layout the screen that is closer to the right receives the most attention [62]. However, two screens in the linear and primary layout are considered the most convenient [62]. One might assume that this relates to the gestalt laws and the effect of visual dissonance, described in the following section.

**B. Subconscious Procession of Visual Perception**

The gestalt laws of grouping describe the mechanics of the mind to reshape the impression of perceived stimuli to a symmetrical and simplified image of reality to decreasing the mental effort [52]. Each element has a relationship with its neighbours and affects how they are perceived. Figure 4 visualizes the following gestalt laws.

**Proximity:** When elements are arranged together, they are perceived as a group with a semantic relationship. **Similarity:** Visual similar elements are also perceived as semantically similar. **Closure:** Incomplete shapes will be mentally completed, based on the visible fragments. **Prägnanz:** Intersecting elements are divided into basic geometric elements, rather than one complex element. **Continuity:** The Prägnanz enables to mentally identify a visual object that “interrupts” other objects and to perceive the interrupter shape as related. **Common fate:** Elements moving towards the same direction at the same time are perceived as a group of elements that relate to each other. **Symmetry:** Elements arranged in a symmetry are perceived as related. **Familiarity:** Complex visual objects are disassembled into simple geometric objects. Thus, geometric objects can remind of the complex form.

The attention is controlled by the visual difference of the presented items by visual highlights or by carefully placed exceptions [52, p. 75], also known as the visual dissonance. A visual highlight can be created by transparency or saturation, line thickness and continuity, colour, brightness, size and complexity of shape; the exception is created by the breach of a visual pattern, see Figure 5. Note, that overusing the visual highlight and applying it to all presented elements does not highlight anything at all, because it is no longer perceived as an exception.

The spatial arrangement of geometric shapes impacts their memorability [44]. Different media types are perceived with a different priority [52, p. 70]: images and geometrical shapes are focused at first, headlines second and text lastly. The attention flow is gender specific: women are more aware of navigation elements and text, whereas men directly focus on images [52, p. 72]. Furthermore, the attention flow depends on the individual expectation where each element should be placed inside the interface. Figure 6 on the following page depicts such expectations for different interaction elements on e-commerce web sites from the year 2005. The expected positions might have changed since then, e.g. the location of the internal navigation can be found nowadays horizontally aligned to the top, but the principle of users having expectations about the position of certain functions remains valid. Expectations are influenced by conventions, culture and individual experiences with different design styles.

**C. Automated Acting**

The memory contains explicit and implicit information. Explicit information consists of semantic knowledge and can be recalled and communicated to others, whereas implicit information consists of procedural knowledge that orches-
Fig. 6. User expectations about the position of interaction elements within e-commerce websites in percentage [52, p. 73].

Fig. 7. Automation threshold of task and sub-task processing [52, p. 101].

V. CONCLUSIONS FOR PRACTICAL APPLICATION

Known design, usability and user experience principles also apply to adaptive, reactive and responsive interfaces regarding general issues that apply for the majority of graphical user interfaces, such as the ISO 9241-110 guidelines [10]. However, the nature of changing interfaces introduce new challenges as time becomes a new dimension to design for. Therefore, in addition to the existing design principles, which provide guidance for the design of static user interfaces, new principles are required that guarantee a good user experience for user interfaces that change their visual appearance during the usage. Based on the gaps identified in current research and on the knowledge about the identified human characteristics we propose the following guidelines as being relevant to effective AUI design:

1) Support automated action whenever possible. Avoid every interruption of learned chains of action. Spatial stability is the prerequisite for automated action, see Subsection IV-C on the preceding page.

2) Always favour a non-destructive approach, such as replicating, over a destructive approach, such as moving. Automatic changes should only offer beneficial support, see assessment of adaptation techniques in Section III on page 2. It must not change the way users are used to interacting with the system or even break conventions, see importance of expectations in Subsection IV-B on the preceding page.

3) Provide the same functionality across all target device classes, unless features are device class specific that they cannot be realized similarly at other device classes. Because users will model how to interact with the product, not with each specific device variation.

4) Consider that changes applied to the interface might affect aspects of the gestalt laws. Intentionally harnessing the gestalt laws by adaptation can attract the user’s attention. E.g. automatically moving items slightly to harm the visual conformity as in the arbitrary experiment design of [62]. Semantic groups can be created dynamically by the principle of proximity, etc.

5) Consider that highlighting an item not only affects the item but also the relationship to its neighbours. Carefully define the maximum visual dissonance that shall be achieved that way, see visual dissonance in Subsection IV-B on the previous page.

6) Guide attention to automatic changes by visual dissonance for changes that require action and movement and highlighting animations that require only attention.

7) Guide the user’s attention to changes that occur on the interface. Carefully select the design and interaction means to obtain the user’s attention. Avoid interruptions of interaction flow, like confirmation pop-ups. Every element designed to catch the user’s attention exogenously shifts away the attention where it has been focused before. Extensive use of this technique will annoy users as it consistently overrides the users choice, see attention flow in Subsection IV-A on page 5.

8) Avoid a high frequency of changes to the interaction elements on the screen. The less the better, unless the user expects updates, e.g. for displayed data within a button label. Consider time as an additional dimension to design for. Favour small incremental changes over wholesale changes [55].
Future work includes the application of these principles to information systems as well as their methodological evaluation.

REFERENCES


